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Computer-Aided Navigation And Drafting System For Revetment Construction Floating Plant

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The Memphis District of the U.S. Army Corps of Engineers is seeking to automate its revetment construction activities through application of the Global Positioning System (GPS) and Computer-Aided Design and Drafting (CADD) technology. This effort uses real-time differential GPS techniques to position the floating plant and the concrete revetments as they are being built. The positions are displayed on an on-board computer workstation to guide construction operations. Digital as-built files also are created for integration into a broad engineering database. A prototype system has been installed and is being evaluated.

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COMPUTER-AIDED NAVIGATION AND DRAFTING SYSTEM

FOR REVETMENT CONSTRUCTION FLOATING PLANT

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BIOGRAPHY

Anthony R. Niles is a Mechanical Engineer in the Precise Survey Branch of the Surveying Division in the Topographic Developments Laboratory of the U.S. Army Engineer Topographic Laboratories (USAETL). He graduated from Old Dominion University in 1985 and began work at USAETL in development of astronomic azimuth software for field artillery. Mr. Niles has also helped develop software for geographic datum transformations and has developed a photogrammetric test facility for dynamic positioning systems. Mr. Niles received a Masters in Mechanical Engineering from The George Washington University in 1991.

Harold L. Smith has a B.S. in Geological Engineering from the University of Mississippi and an M.S. in Civil Engineering from Memphis State University. He began work at Memphis District in 1973 as a Civil Engineer in the Geotechnical Engineering and Surveying Branch. Since 1983, he has worked as Chief of the Engineering Data Section for that Branch. The section is responsible for topographic, hydrographic, cadastral and geodetic surveys utilizing both hired labor and architect-engineer contracts. He is also responsible for the District Soils Laboratory and the Surface Exploration Parties.

ABSTRACT

The Memphis District of the U.S. Army Corps of Engineers is seeking to automate its revetment construction activities through application of the Global Positioning System (GPS) and Computer-Aided Design and Drafting (CADD) technology. This effort uses real-time differential GPS techniques to position the floating plant and the concrete revetments as they are being built. The positions are displayed on an on-board computer workstation to guide construction operations. Digital as-built files also are created for integration into a broad engineering database. A prototype system has been installed and is being evaluated.

PROJECT BACKGROUND

River Stabilization

The Memphis District is one of several U.S. Army Corps of Engineers (USACE) district with extensive construction and maintenance activities associated with the Mississippi River. The purpose of these activities is the improvement of the flood-carrying capacity of the river and stabilization and maintenance of a permanent navigation channel. Efforts are directed toward obtaining an alignment which is compatible with the river's natural tendencies, but will effectively pass flood flows and be suitable for navigation. Continual and intensive studies of the river's behavior determine the proper alignment, and revetments, dikes, and dredging are used to help the river develop and hold proper alignment.

A master plan of river improvements to be performed by the Memphis District calls for the construction of 397 miles of revetment and 205 miles of dikes. To date, 359 miles of revet-

ment and 148 miles of dikes have been completed. Project completion is currently scheduled for 2010 with maintenance continuing indefinitely.

In 1989, development was started in the Memphis District on a Geographical Engineering Management System (GEMS). This system is to integrate on a digital platform all the various management, analysis, design, construction and maintenance activities using Intergraph hardware and software. Most existing and all future engineering data will reside in a database which will include but not be limited to aerial photography, revetment and dike as-builts, revetment re-surveys and survey control. A remaining phase in the project that has yet to be automated is the revetment construction.

Revetment Construction

Revetments are generally placed on the outside banks of bends in the river where flows are most destructive. The method used to construct the underwater portion is unique and the result of years of research and development. The actual construction procedure is a complex coordination of heavy machinery and over 200 personnel.

Before placing the revetment, large floating drag lines smooth the bank to a stable slope from the top to well below the waterline. The underwater portion of the revetment is an articulated concrete mattress (ACM) consisting of individual concrete units measuring approximately 2 X 4 feet and 3 inches thick. The units are held together by wires embedded in the concrete.

At the construction site, the concrete units are assembled on the sloping deck of the mat plant into a mattress connected to launching cables which are anchored to the bank. As assembly of the mattress progresses, the mat plant moves riverward along a mooring barge, allowing the assembled mattress to slide over the edge. When the mattress has covered the river bottom out to the desired distance, the launching cables are cut and the barges are moved upstream to lay the next mattress. This process is repeated in an upstream direction until the desired length of bank has been revetted. The remainder of the bank above water is then covered with stone. Figure 1 shows the mooring and mat barges as an ACM is being deployed.

Accurate placement of the ACM is vital to bank stability and economic construction. The main objective in mat placement is to achieve an overlap of ten feet. This assures minimal waste in materials yet produces a stable and effective mat coverage. For over fifty years the positioning of the mat has been accomplished by first constructing a monumented baseline landward of top bank. Then a tempory baseline is established near mid-bank. During construction, points along the temporary baseline are occupied with a conventional transit. The transit is located at stations as required to provide a ten foot overlap between mats. The transit operator sites along the downstream edge of the mooring barge and directs positioning using hand signals. The deck foreman then issues instructions to winch operators to achieve the desired barge alignment. Once the mooring barge is in place, the mat plant is moved landward until the plant strikes the bank. Figure 2 shows the transit being used for barge positioning.

Once the mat plant has been moved into position at the bank, the assembly and deployment of the ACM begins. The leading edge of the ACM is anchored to the bank and the transit determines the coordinates of the landward corners. During deployment, the transit continues to monitor the position of the mooring barge. This information is used to draft temporary as-built drawings at the construction site. These temporary drawings are subsequently redrawn at the district office to develop permanent as-built engineering drawings of each revetment.

Automation of the revetment construction has been considered for several years. However, the logistics requirement of an all-weather system has prohibited any change in the methodologies previously discussed until now. With the recent developments in Differential Global Positioning System (DGPS), an Integrated positioning and Computer-Aided Design and Drafting (CADD) system is now feasible and is being developed for revetment con-

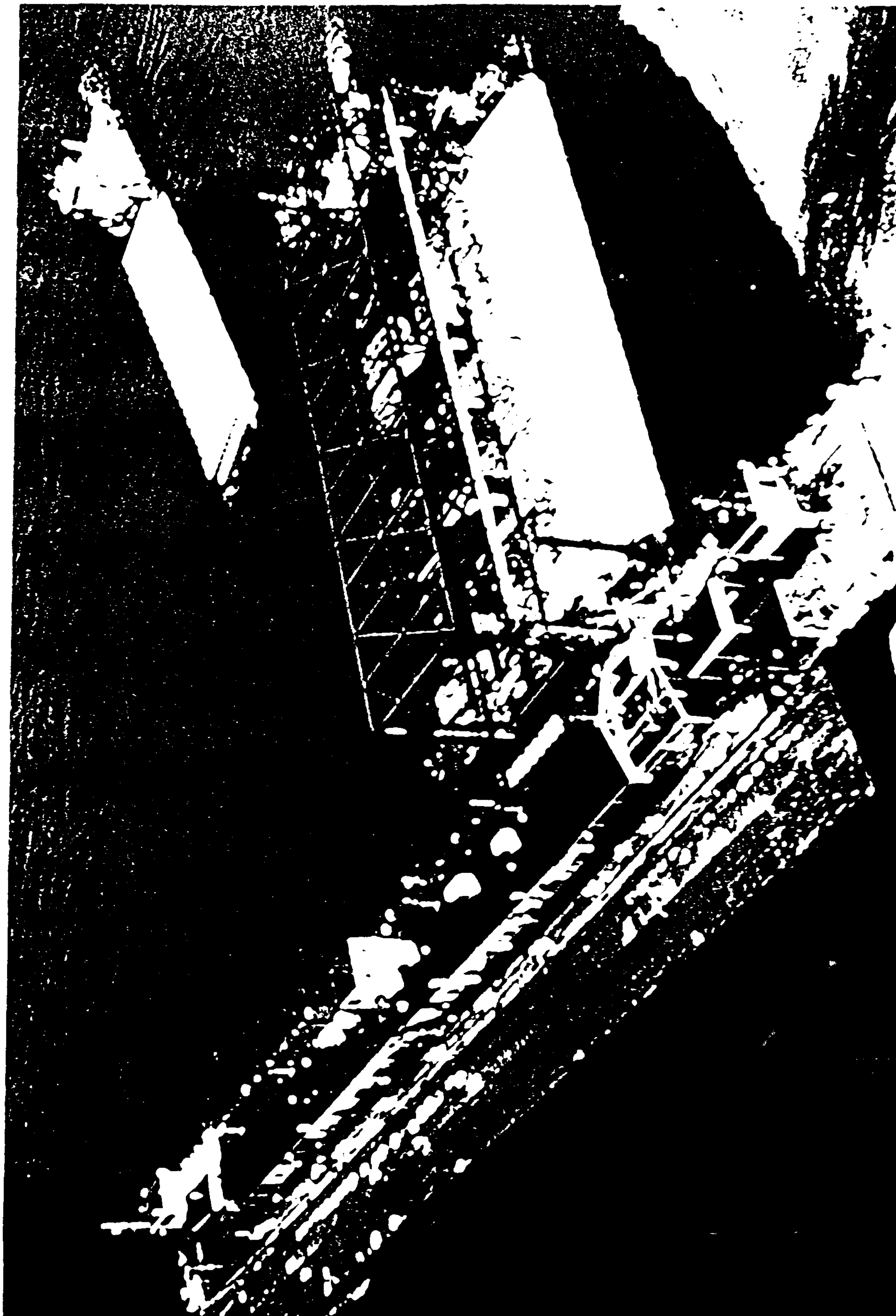

Figure 1

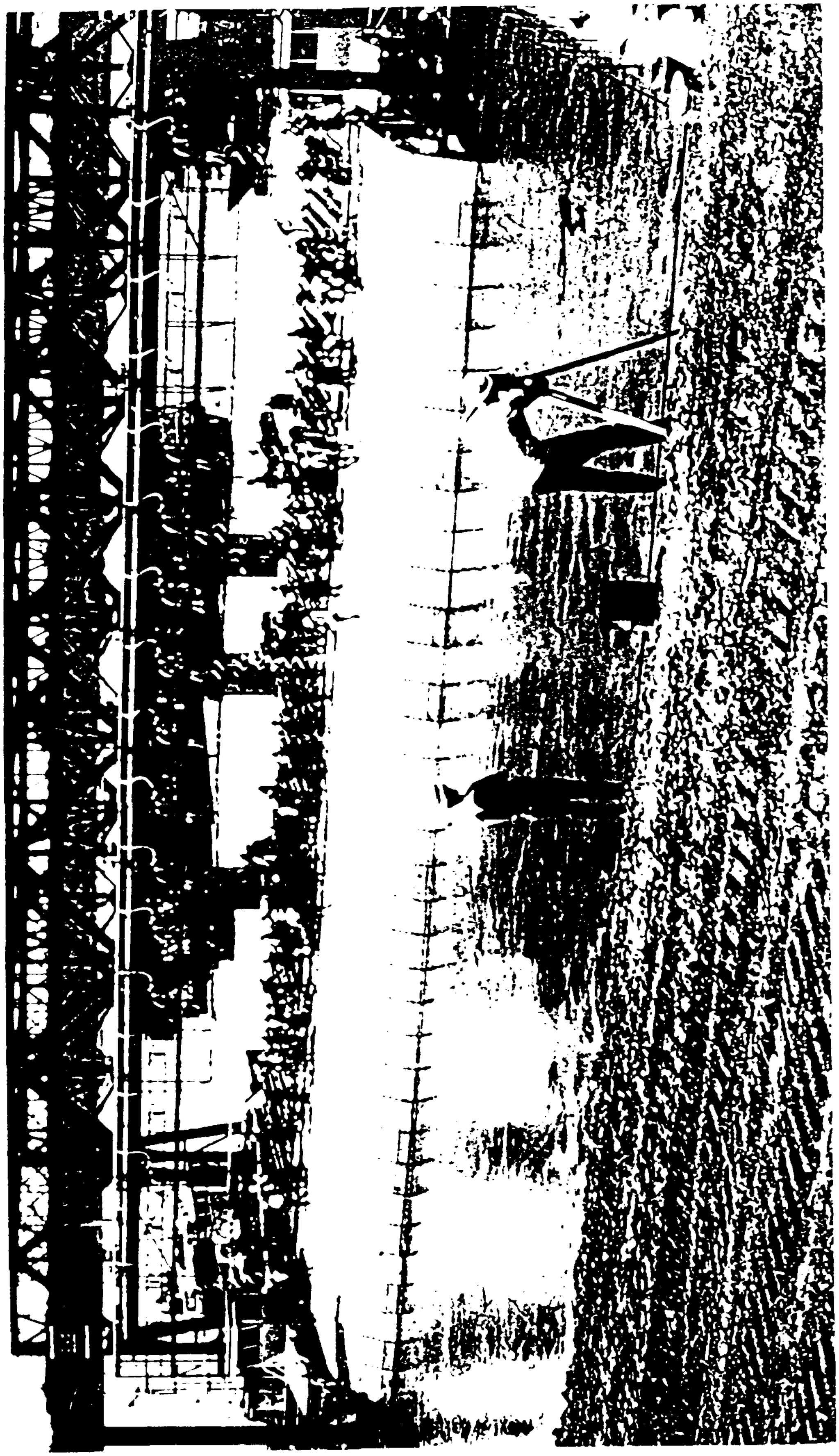

Figure 2

struction operations.

COMPUTER-AIDED NAVIGATION AND DRAFTING SYSTEM

The Global Positioning System and current engineering computer workstation technology offer an automation method for revetment construction that can be integrated with the GEMS. DGPS is used to position the floating plant with little or no human intervention and the workstation displays the barge positions to guide construction operations and produce as-built drawings in real-time.

Positioning System

Real-time DGPS is used to position the mat barge to meter-level accuracy. A Trimble SST Marine Surveyor occupies a reference point on-shore one to six miles from the floating plant and provides pseudo-range corrections for the barge stations. Two Trimble 4000SL receivers occupy each end of the mat barge to determine location and orientation. The antennas are mounted atop the superstructure for clear and unobstructed satellite communications. Figure 3 illustrates the location of the barge and reference GPS receivers.

GPS positions of centimeter accuracy are possible through the post-processing of carrier data from the reference station. During the evaluation phase these positions will be used as a reference for accuracy analyses of the pseudo-range positions and the conventionally determined coordinates. Eventually, as on-the-fly ambiguity resolution becomes possible, a real-time system of centimeter accuracy will replace the meter level system.

The reference GPS receiver is interfaced to a DataRadio modem and General Electric 407.3 MHz radio for data transmission. This radio should enable the reference station to be positioned up to twenty miles from the construction site. Range corrections are sent to an operator station in a deckhouse on the mooring barge, where an Arlan muliplexer and an Arlan 130 radio relay the corrections to the mat barge receivers. The corrected positions are computed and sent by Arlan 130 radios back to the operator station where the coordinates are read into a DataWorld 386 PC computer. Figure 4 illustrates the data communication network. The PC converts the latitude/longitude positions into grid coordinates and then passes the coordinates to the workstation at the rate of one position every four seconds. The PC also collects the carrier-phase data in ASCII format from the GPS reference station and logs the data in ASCII format on a 250 Mbyte tape. Connections between master radio station - PC - workstation are through RS-232 interface.

CADD System

The data communication PC is interfaced to an Intergraph InterPro 225 computer workstation with 19 inch monitor. Using the Microstation graphics routine, the barge and mat positions are displayed over a design drawing of the construction area. The outline of the mat and mooring barges are displayed and updated every four seconds. With the known geometry and dimensions from the GPS antennas to the barge deck, the location of each side of the ACM as it leaves the barge is known. The ACM is shown as it is being deployed, and completed mats are shown in their final as-built positions. The program is to be modified to display the current overlap, in feet, of the mat being deployed with the previously laid mat. The as-built digital files are then returned to the district office for incorporation into the GEMS.

Because the mat and mooring barges occasionally remain stationary during construction operations, statistically refined positions are possible. The operator indicates through key-in the beginning of a static period and the workstation begins logging DGPS positions and continues until the operator indicates end of static period. A mean position is then computed and used as a refined ACM position in the as-built drawing. This procedure would typically be used at the beginning of mat deployment when the landward edge of the ACM is being anchored to the bank. Such a stationary period also occurs as a new section, or "launch", is added to the ACM.

The workstation is located with the master communication station in one of two deckhouses on the mooring barge. A system operator monitors the GPS receiver and workstation operations and provides workstation inputs, such as static period start/stop indica-

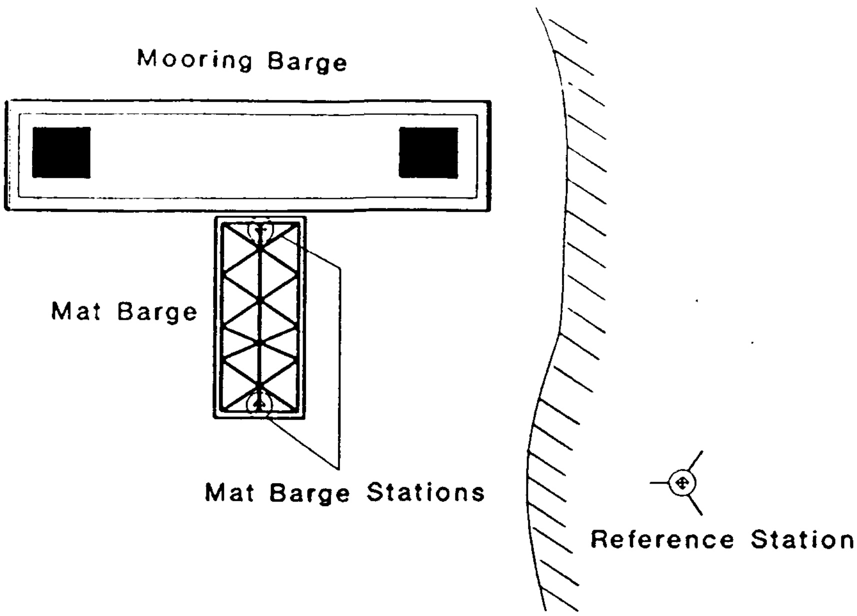

Figure 3: GPS Receiver Locations

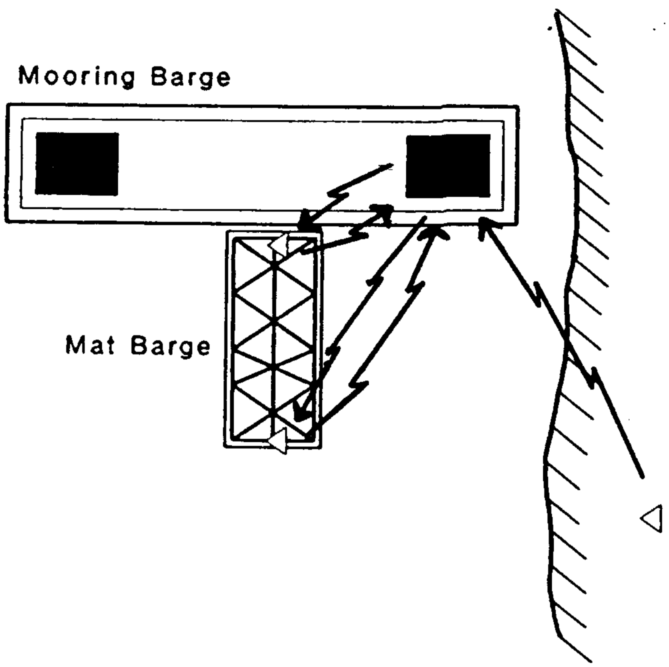

Figure 4: GPS Radio Configuration

tions and beginning and end of ACM deployment. A remote monitor is located on the mooring barge deck near the deck house for the construction foreman to observe for barge positioning.

A current system limitation is the system's location at one end of the mooring barge. The barge foreman monitors construction operations at the landward end of the mooring barge where most activities occur. The end of the mooring barge anchored to the bank depends upon the side of the river on which construction is occurring. Therefore, the system operator is in clear view of the construction activities only when that end of the barge is near the bank. Eventually, either a dual system or a remote graphics terminal will be installed to solve this problem.

Development Procedure

Development of the Computer-Aided Navigation and Drafting System began in February 1991 in a cooperative effort between the Memphis District and The U.S. Army Engineer Topographic Laboratories (USAETL). Workstation software development and system integration and testing was performed by USAETL and the GPS data communications system was developed by John E. Chance and Associates. All hardware are commercially-available off-the-shelf items. The total navigation and drafting system was integrated and installed on the construction barges in mid-July in time for the July 22 start of the construction season.

The navigation and drafting system is currently being tested and evaluated, and will be modified as necessary. The conventional method using a transit and manual drafting will continue to be used as the primary method of positioning and producing as-built drawings. However, construction personnel will be introduced to the new technology and will provide suggestions for improvement of the system. It is anticipated that the new system will be fully integrated and in use during the 1992 construction season.

CONCLUSION

The implementation of the Computer-Aided Navigation and Drafting System on the revetment construction floating plant will result in cost savings and will provide an important link in the GEMS. The automation will initially eliminate the temporary baseline requirement and eventually eliminate the permanent baseline requirement. Experience with DGPS in other applications indicates that the shore reference station can be located at least 30 miles from the worksite without any accuracy degradation. DGPS technology in the near-future will also enable positioning accuracy far greater than the conventional method currently used. The savings of more than $150,000 in the first year of operation will more than pay for the hardware and software development of this system.